THREE DECADES OF WIPP UNDERGROUND OPERATIONS – SUCCESSES AND LESSONS-LEARNED

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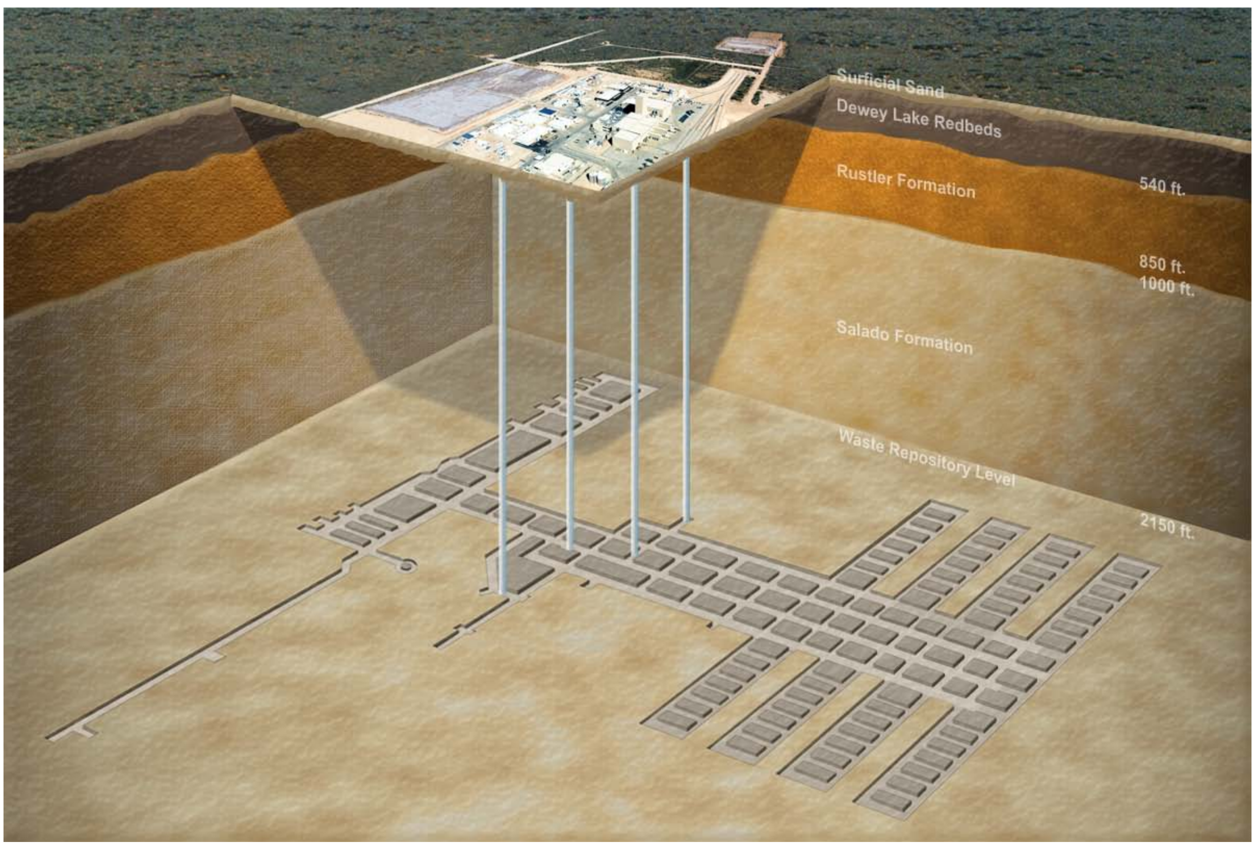
The U.S. Department of Energy's (DOE) Waste Isolation Pilot Plant (WIPP) has been receiving and disposing transuranic (TRU) waste in the bedded salt of the Permian basin for more than eleven years. As of May 2010 over 67,000 m^3 of waste has been disposed in over 130,000 containers. This represents about 8,500 over-the-road truck shipments covering over 10,000,000 loaded miles (16M km).

View of WIPP Surface and Underground Facilities



BACKGROUND AND HISTORY

The WIPP story began in the 1950s when the National Academy of Sciences proposed that burial in salt was a promising method for disposing radioactive wastes. In the 1970s, the U.S. Atomic Energy Commission chose the area in southeast New Mexico for study and exploratory work. Salt deposits in the vicinity of the WIPP are well-known and understood due to the presence of potash mining and petroleum exploration and extraction operations. The salt beds at WIPP are about a half mile (1 km) thick.

By 1979 the U.S. Congress had authorized the WIPP as a research and development project for disposal of defense-generated TRU wastes. The first shaft work began in 1981. Much of the mine development work since that time has been performed by miners who have come from the local potash industry. These personnel have proven to be an available and capable labor pool.

A Site and Preliminary Design Validation (SPDV) program was developed to characterize the site and obtain geotechnical data. The SPDV program was used to confirm that the site was suitable for permanent disposal of the planned wastes against and complied with established design criteria. Geotechnical monitoring has continued from the beginning to confirm repository performance and to ensure operational safety.

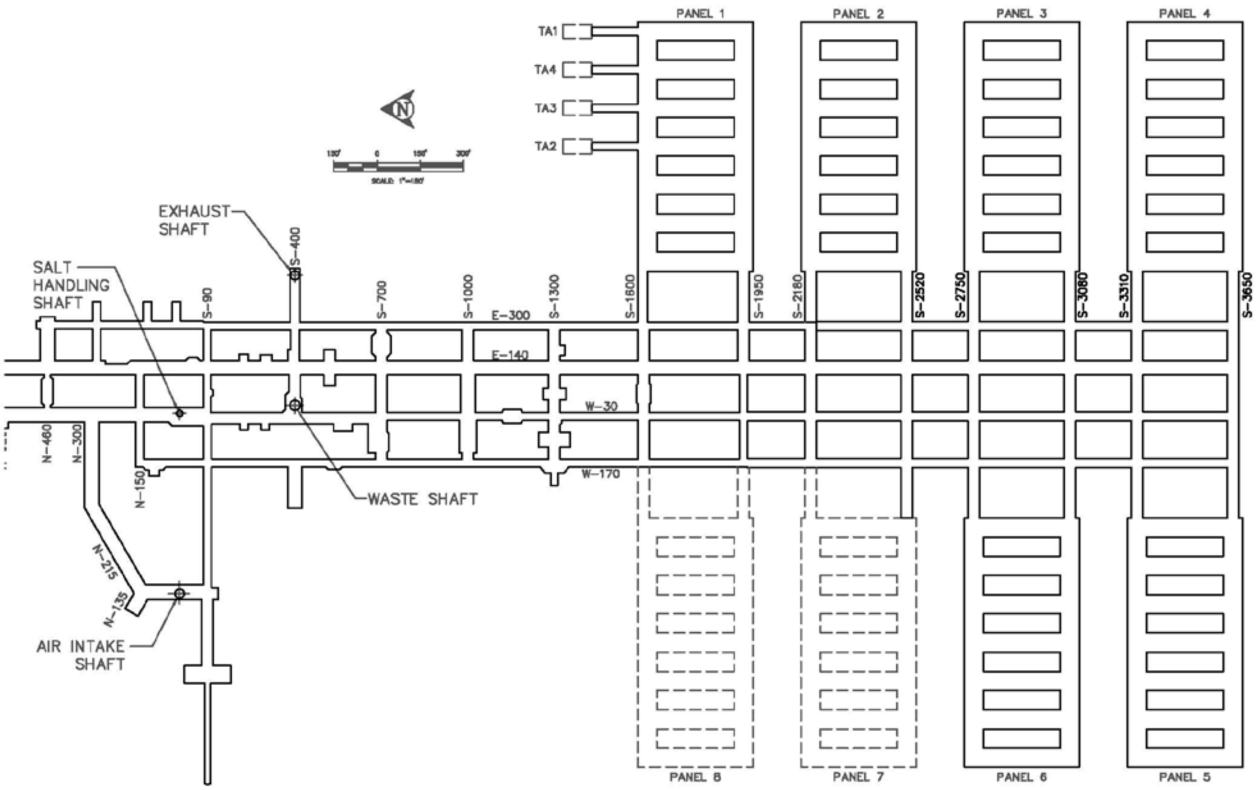
From 1982 through 1986 the underground facility was developed using continuous mining machines and diesel powered haulage equipment. This development included mining of the main drifts and their attendant cross drifts and a simulated disposal panel consisting of four full-sized (13 ft. [4 m] x 33 ft. [10 m] x 300 ft. [91 m]) rooms. In addition, experiments were fielded to investigate the behavior of the site salt deposits including geomechanical response to various excavation geometries and exposure to simulations of heat generating waste. Other experiments studied hydrologic properties and still others investigated the concepts for plugging and sealing the repository.

The results of the validation activities confirmed initial expectations about repository geology and mining operations. It was confirmed that WIPP salt beds are uniform, continuous and relatively level across the facility. It was found that excavation using modern continuous mining equipment could be performed precisely and can be done relatively quickly, easily and economically. The finished openings are clean and dry and any salt dust generated can be controlled with water. The natural reflectivity of the salt also helped provide well lit areas.

Geomechanical data collected validated the expectation that the openings creep and close over time, with the highest response rates observed immediately after excavation (feet per year) and decaying down to a steady state creep rate over time (inches per year). These geomechanical data were found to be useful in understanding ground conditions and in determining when and where to install any ground support needed to preserve opening integrity and ensure operational safety.

By 1986 studies were sufficiently complete to conclude that the underground facility could be developed as planned. That same year work commenced on mining the first of eight planned waste panels (Panel 1). Each was designed to consist of seven rooms where remote handled (RH) waste canisters could be emplaced in boreholes in the ribs and drums and other contact handled (CH) containers could subsequently be stacked in the rooms. This first panel, termed Panel 1, was completed in 1988. However, the regulatory environment delayed WIPP opening. Panel 1 stood open and ready from that time until all required permits were acquired and first CH waste emplacements began in 1999.

WIPP Disposal Area Layout



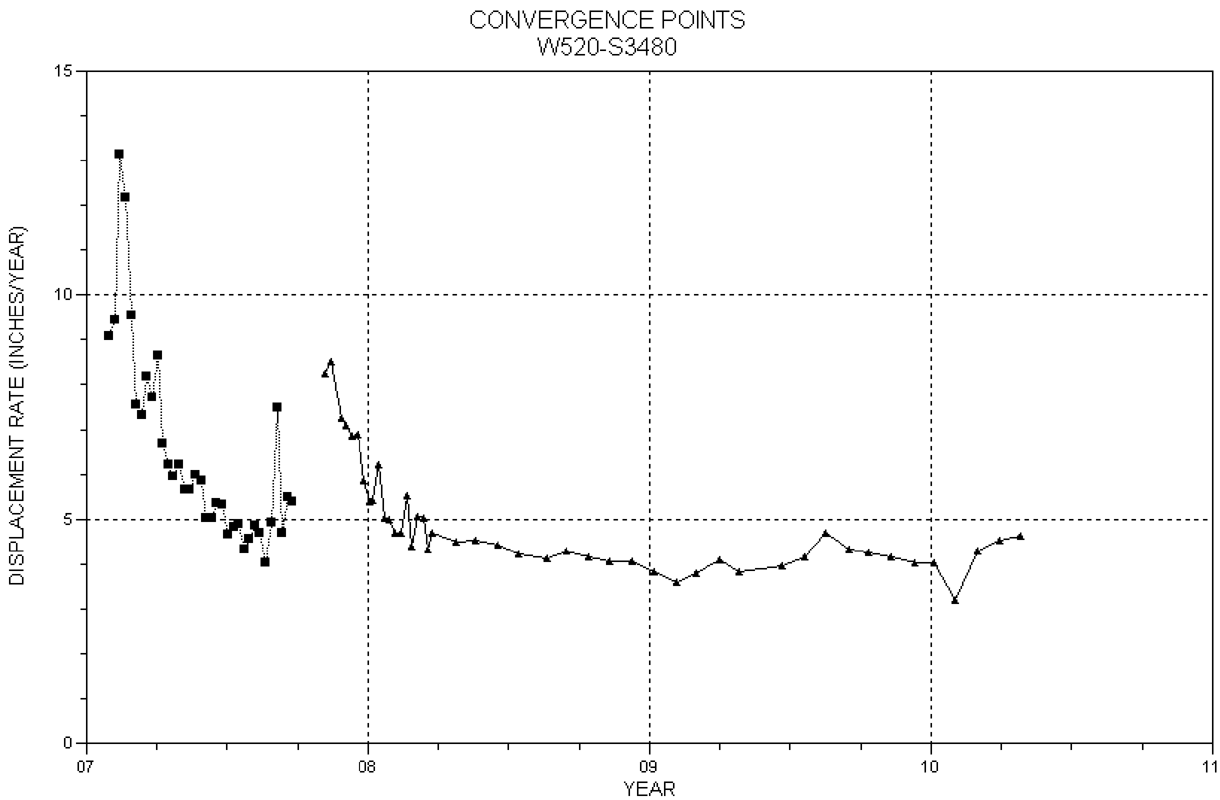
UNDERGROUND OPERATIONS – EXPERIENCE TO DATE

After almost 30 years since the initial excavation began, the WIPP underground repository continues to be stable and to comply with the original objectives and requirements. The repository continues to be mined and developed as disposal space is needed. The underground footprint is essentially unchanged from its original eight-panel design. Excavation performance has met, and continues to meet, design requirements. Although the original life of the facility was expected to be only 25 years, start-up delays and modified project priorities have pushed its expected life well beyond that. Even with these challenges there is confidence that with continued maintenance the repository will continue to perform adequately and meet desired extensions.

Geotechnical monitoring continues in all areas accessible to personnel, not only to confirm long-term performance, but also to ensure operational safety. This monitoring includes surface subsidence monitoring and underground geomechanical monitoring (e.g. convergence monitoring and roof dilation) at literally hundreds of locations, visual observations including mapping and tracking fractures that develop, and investigations in observation holes. Particular attention is paid to those areas where local geology (e.g. localized bedding features) may impact ground conditions.

Where openings are comparatively large (tall or wide), convergence rates are typically higher than in smaller cross sectional openings. Since waste disposal rooms are among the largest and widest at 13 feet (4 m) high, 33 feet (10 m) wide, and 300 feet (91 m) long, it is not unusual to have as much as a foot (0.3 m) of convergence in the first year after excavation when the ground response is highest and three to five inches (8-13 cm) per year thereafter. Although this convergence is desirable for entombing waste, it is a factor that must be taken into account during the operational phase. If the rooms are not used in a timely manner, this convergence would progress to the point that the disposal room clearance is not sufficient to perform waste handling operations. This lesson was learned early when delays in permitting left Panel 1 ready, waiting for a decade. Before emplacement operations could begin in these areas, it was necessary to renovate them by re-excavating the floor and ribs to reestablish the necessary operational clearances and flat working surfaces.

Example of a Typical Convergence Rate over Time



NOTES:
1. Excavation date: August 2006.
2. Reinstalled "C" point after mining October 2007

The first years of WIPP disposal operations were limited to emplacing CH waste drums and other containers. In 2006 regulatory approval was granted to begin disposal of RH waste canisters. Beginning in Panel 4 these canisters have been emplaced in 30 in. (76 cm) diameter holes drilled 17 ft. (5 m) deep typically every 8 ft. (2.4 m) along the ribs of the disposal rooms. Computer modeling of this layout was used to predict expected geomechanical response of drilling these holes. Again, geomechanical monitoring was used to validate the concept and plan.

Typical Waste Disposal Room

Today, with the repository now receiving both CH and RH waste on a regular basis, disposal panels are prepared just-in-time, that is, the panel excavation, outfitting, and regulatory certification are completed a few months before the waste disposal schedule requires them to be available. Panels are fully mined and outfitted with ventilation controls, lighting and communications systems while the previously completed panel is being filled with waste. Panel rooms and drifts are mined to a height and width that takes into account the convergence projected to occur prior to and during waste emplacement. Similar to the rooms, RH boreholes are only drilled as needed and these are, likewise, drilled just in time. Just-in-time mining levels the work-load of both personnel and equipment making it an efficient work method. In addition, this timing provides younger openings which are more stable and hence require less maintenance during the disposal cycle. This minimizes the potential for conflicts during waste disposal operations.

Some of the main access entries are now nearing 30 years of age. These are openings that must remain used and useful for the life of the facility. These openings receive regular maintenance and renovation when necessary. Renovation is relatively easy and has been done in a variety of ways. Most commonly the floor is re-leveled by watering and dragging mined salt on the roadway and occasionally the walls are trimmed. As the roof creeps and expands roof bolts are put into material yield and may fail. They are replaced as necessary to maintain the integrity of the ground support. In some cases a continuous miner may be used to excavate the floor or roof to re-establish operating clearances or remove loose fractured ground.

LESSONS LEARNED

Although safety is emphasized in the mining industry, by necessity WIPP extends this emphasis to the underground repository at the levels expected of a DOE nuclear facility. Safety is emphasized for personnel and extends to the facility and the public through both occupational and nuclear process rules. WIPP has been awarded "Mine Operator of the Year" honors for 22 of the past 23 years by the New Mexico Mining Association. This is based on the fact that WIPP incident and injury rates (0.17 injuries per 200,000 work-hr. in 2008) rank far below the national averages for operating mines (3.13 in U.S. non-metal mines in 2008 – Source: U.S. Mine Safety and Health Administration web site). The lesson to be learned is to set clear safe work expectations and to train operators on the best methods to achieve them. The WIPP safety culture emphasizes clear expectations, good communications, operator feedback, recognition of good performance, and continuous improvement. These concepts are institutionalized and taught to all employees and contractors beginning with the first classroom training and flow through procedures and work instructions.

Another lesson learned is the need to consider and, whenever possible, plan for additional requirements and changing priorities. The original throughput capacity for the facility was to handle 17 CH and two RH shipments per week. Current throughput rates are about 30 CH and five RH shipments each week. To accommodate the increase, surface waste handling facilities were modified and augmented. The increase also impacted the rate that panels were required to be mined and prepared. The panel completion rate could be increased fairly simply by hiring more employees and running additional equipment. However, a challenge developed due to the limits of hoist availability and capacity.

The problem was solved by adding an additional work shift to mine and hoist salt and by stockpiling or surging excess mined salt underground, and then hoisting it to the surface during a subsequent late shift. Hoisting on the late shift was found to more efficient due to the ability to dedicate hoist time to mucking operations. This stockpiling process involves double handling of a portion of the mined salt and incurs some additional handling cost, but this additional cost was justified by faster removal of waste from generator sites. The lesson to be drawn from this experience is to design a repository to be very robust and capable of adaptation should priorities change.

Given that convergence rates and associated deterioration are somewhat higher for larger openings at WIPP it would have been advantageous if opening sizes would have been minimized. Although the size of equipment may have little impact if used on the surface it will require a large opening in which to operate in the underground if the operating envelope is large. This has been found to be especially true for large pieces of RH waste handling equipment such as the Remote-Handled Facility Cask Transfer Car and the large (up to 40 ton) forklifts used at WIPP. The lesson learned is to design large pieces of waste handling equipment, as possible, so as to minimize their operating envelope and, therefore, their potential impact on long-term underground opening performance.

RH Waste Handling Equipment

Another lesson learned is the need to identify and avoid potential single point failures and, as possible, to mitigate them in the design stage. Additional equipment and spare parts have been procured and added to inventories to address identified single point failure situations. However, the facility itself presents that possibility since waste transportation from surface to the disposal panels is currently only possible via the Waste Shaft and the East 140 drift. To date this has not been a problem, but as the facility has aged ground control maintenance requirements in the underground have increased. If unplanned or major maintenance becomes necessary no alternative currently exists, but to suspend waste disposal operations in the underground while performing the maintenance work. WIPP is currently pursuing the possibility of modifying another main drift to serve as an alternative waste transport route, so openings maintenance can be performed in the East 140 drift while continuing to transport and emplace waste.

The mining industry lends another lesson to be considered. In many underground mining operations a retreat sequence is used to extract the ore. That is, access drifts, mains and any “first mining” areas are typically excavated in a sequence that progresses from the shafts to the ore body edge, end of a panel, or to the lease boundary. Then the maximum amount of ore is mined or “second mining” commences at the extremity and progresses by “retreating” back toward the main access and shafts. This is advantageous for several reasons. Typically, the mining face, where the mining is taking place, is immediately adjacent to a solid barrier or pillar where stability is best. Also, this better ensures pillar stability near the shafts. The ore can be transported back safely through mains in the relatively solid pillars to the shafts where it can be hoisted out of the mine. The ground that has been mined need not be re-entered, accessed, or maintained further. This ensures safety of personnel and minimizes maintenance requirements.

This retreat process has been employed at the WIPP in the waste disposal process. By design, in each disposal panel, waste is emplaced in the room furthest from the mains first and when it is filled it is closed to access and removed from the ventilation system. Then the process is repeated in the adjacent room. This sequence of retreating out of a panel continues until the panel is filled and closed. Although the retreat process is used in panels, the WIPP long-term plan requires the panels to be filled in a rotational sequence around the main entries, which are then filled on retreat. This has some theoretical advantages, but these are far outweighed by challenging operational ventilation configurations and the additional maintenance and renovation work required by the existing sequence. A lesson learned might be that if the original design had allowed for the panels located furthest from the shafts to be filled first and their mains to be subsequently filled and closed, costs associated with long term maintenance of the aging mains may have been substantially reduced over the life of the project.

A final lesson is to simply conclude that the WIPP repository continues to be stable and to comply with the original objectives and requirements despite the challenges encountered in mining as well as those associated with operations and changing project direction. Salt has proven itself an excellent medium for permanent disposal of radioactive waste. The WIPP continues its mission today and will continue to operate safely and compliantly to dispose of the nation’s waste.